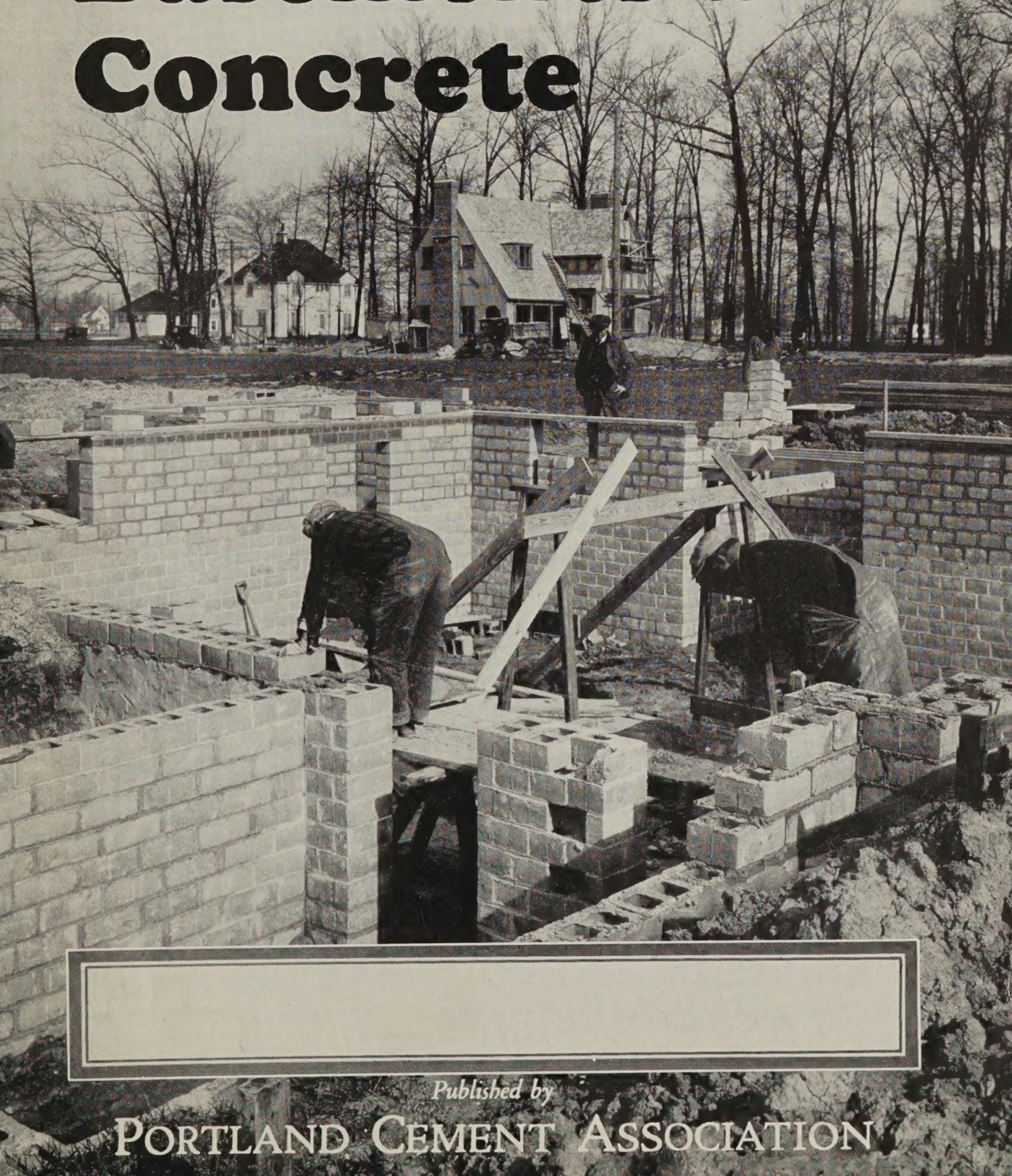
Foundation Walls *and* Basements *of* Concrete



Published by

PORTLAND CEMENT ASSOCIATION

DRY BASEMENTS OF CONCRETE

A DRY basement, properly lighted and adequately floored, adds valuable space to any building. The principal use for below-grade space is as storage and service rooms. When adequately day-lighted and floored, basement space has uses which are unlimited. Working and living conditions can be made equal to those in above-grade interiors if recommended construction methods are followed. See pages 15 and 17 for methods of insuring dry walls and floors in basements.

Concrete for Permanence

Foundation Walls *and* Basements of Concrete

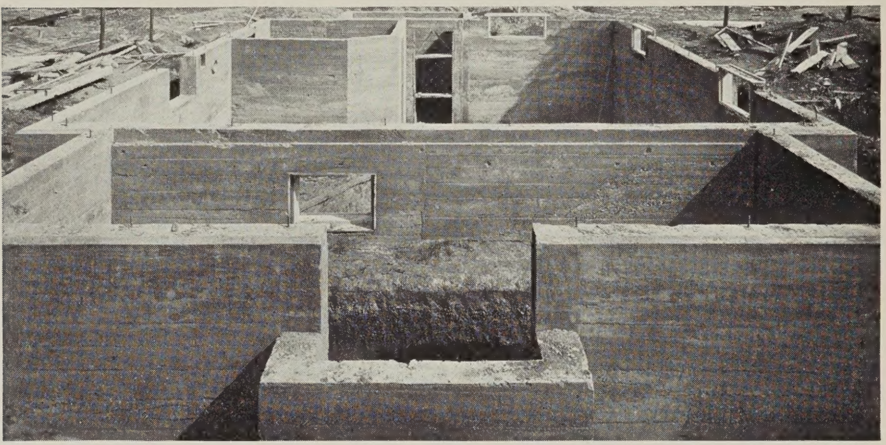
A STRONG, durable foundation is the first requirement for every good building. Whether the structure is a towering skyscraper or a one-story building, concrete footings and foundations are a necessity.

Concrete foundations prolong the life of buildings because they insure uniform distribution of the weight on the soil, thereby preventing settlement and consequent cracking of walls and retaining the structure in first-class condition at minimum maintenance cost. Such foundations likewise are ratproof, fireproof and permanent.

Concrete foundations are the only known barrier against termites which eat and often destroy wooden structures. Extermination of these wood-boring insects is practically impossible and the only effective method of limiting their activities is by building them out with high concrete foundations.

Concrete foundations also are proof against rats. Many cities in rat-infested districts have passed ordinances requiring that buildings be made ratproof with concrete floors and foundation walls, because no rat can gnaw through concrete. By keeping rats out of storage buildings, concrete foundations or basement walls in a short time will prevent waste or destruction of foods or other products equal to their cost.

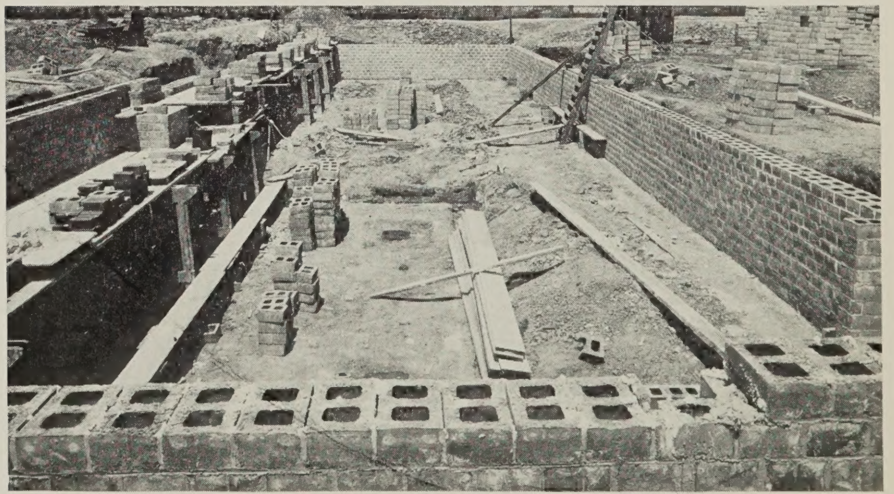
A schoolhouse foundation with concrete building tile. Portions of the work required monolithic concrete construction



A typical monolithic or solid concrete foundation after forms have been removed. Note the projecting bolts for anchoring structure to the foundation

Types of Foundation Walls

Concrete foundations and basement walls are of two types, those made of concrete cast in place and those built of precast units. The latter type, known as concrete masonry construction, often is less expensive than solid concrete which requires the use of forms during construction. Where loads are heavy as in tall buildings, or where there is a severe side thrust of soil as in deep cellars or hillside locations, or where external water pressures are encountered, foundations of solid (monolithic) concrete are recommended. Where unusual strength is required, steel reinforcement and concrete pilasters may be needed.



A typical concrete building tile foundation in process of construction. Such foundations are built quickly at a minimum of expense

It is common practice to place monolithic concrete footings for all types of foundation walls. Such footings provide an even surface on which to start the wall proper whether monolithic or concrete masonry. Also they provide increased bearing area on the soil, thus insuring against settlement.

Computing Dimensions of Footings

In determining the width of footings, the character of the soil as well as the weight of the building and its contents must be taken into account. The footing is made wide enough to spread the load over sufficient area to be safe against settlement. Load-bearing capacities of different soils vary. The following table indicates safe loads for various soils:

Class of Soil	*Carrying Capacity*
Soft Clay	1 ton per square foot
Wet Sand and Firm Clay	2 tons per square foot
Fine and Dry Sand	3 tons per square foot
Hard Dry Clay	4 tons per square foot
Coarse Sand	4 tons per square foot
Gravel	6 tons per square foot

"Dead" load, as the weight of the building commonly is called, is computed by summarizing weights of various portions of the structure. A monolithic concrete wall 8 inches thick weighs about 100 pounds per square foot of wall area. Such a wall 10 feet high puts a "dead" load on the footing of 1,000 pounds per lineal foot. Concrete block walls 8 inches thick weigh about 70 pounds per square foot of wall area. Fifty pounds per square foot is the weight of an 8-inch wall made of concrete building tile. Lumber used in building construction commonly weighs from 2 to 4 pounds per board foot. Brick masonry averages 140 pounds per cubic foot. These weights, although approximate, are sufficiently accurate for figuring "dead" loads in order to compute the size of footing required.

Concrete masonry provides substantial construction for basement walls. The actual loading frequently is only a small fraction of the crushing strength

Determination of "live" loads, those imposed upon the foundation by the contents of the building, largely is a matter of personal opinion based on experience. Building ordinances often specify minimum "live" loads allowable in the design of floors and in such cases these values are used in computing loads on the foundations. These loads vary according to the occupancy of the building. Thus, 400 pounds per square foot of floor area may be the requirement in designing a warehouse for storing hides, while an ordinary dwelling is unlikely to be called upon to carry one-tenth that amount. Most building codes specify 30 to 40 pounds per square foot as the "live" load for floors in dwellings. Schoolhouse floors generally are designed for a "live" load of 50 pounds per square foot. Roof "live" loads are taken at around 20 or 30 pounds per square foot, depending upon the amount of snowfall common in the community.

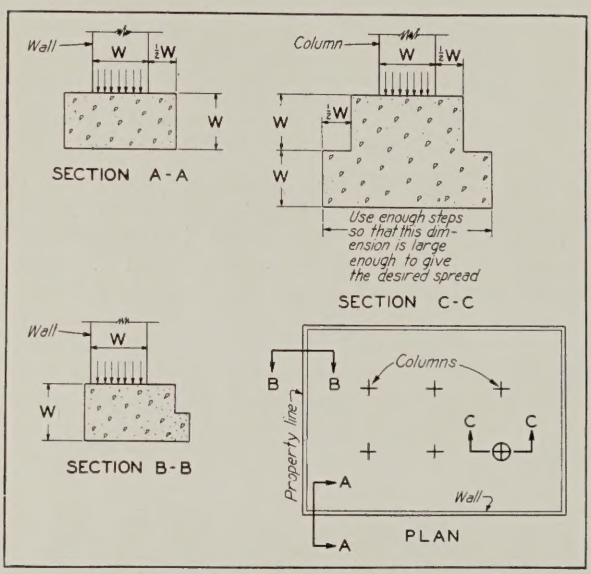


Fig. 1—General guide for the design of simple footings

For the smaller structures which put no great load on footings, a safe design is to make the footing twice as wide as the wall is thick and projecting equally on both sides. (See Section AA in Fig. 1.) The depth of the footing should be twice the projection. If the building is on a property line or adjoining another structure it may be necessary to construct a footing similar to that shown in Section BB, Fig. 1, projecting only on one side of the wall. Under heavily loaded columns the footings are "stepped down" as shown in Section CC, Fig. 1. Note that the projection is one-half the column thickness, and that the depth of each step is twice its projection. "Stepping-down" of footings saves concrete, yet gives the desired spread.

Typical Example of Foundation Design

The following example shows how the width of footings is calculated for a two-story concrete masonry residence. (See cross-section and plan, Fig. 2, on page 7.) The building is assumed to be located on soft clay soil that has a safe bearing capacity of 1 ton per square foot.

Combined live and dead loads are assumed as follows:

First floor	50 pounds per square foot
Second floor	50 pounds per square foot
Attic	20 pounds per square foot
Roof (including wind pressure)	40 pounds per square foot
Weight of 8″ concrete block wall	70 pounds per square foot
Weight of 10″ concrete block wall	80 pounds per square foot

No deduction made for door or window openings.

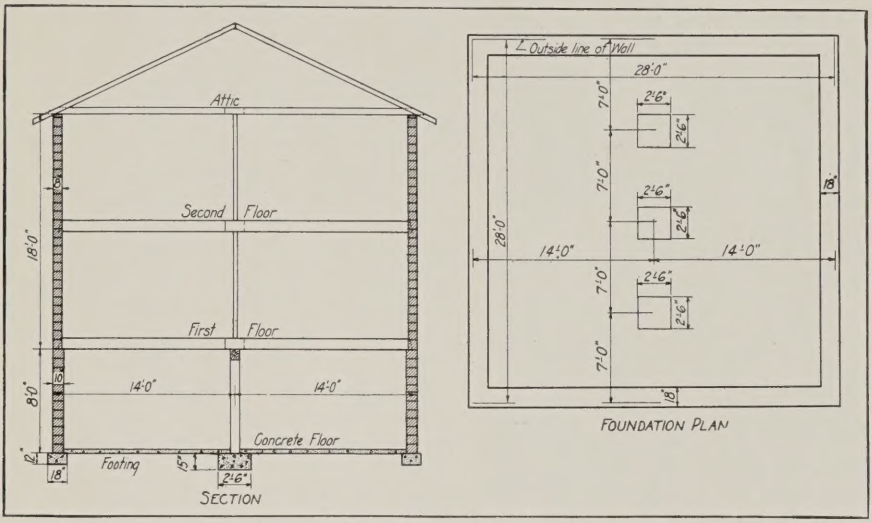


Fig. 2—Typical section and plan of two-story residence

Load on Wall Footing Per Lineal Foot

10-inch basement wall, 8 ft. high, 8 times 80 lbs.	=	640 pounds
8-inch super-structure walls, 18 ft. high, 18 times 70 lbs.	=	1,260 pounds
1st and 2nd floor loads, supported on walls, ½ span, 2 times 7 times 50 lbs.	=	700 pounds
Attic floor walls, ½ span, 7 times 20 lbs.	=	140 pounds
Roof load, area times load divided by perimeter	=	280 pounds
Total load on footing per lineal foot		3,020 pounds

Since 1 square foot of soft clay soil will bear 1 ton (2,000 pounds), approximately 1½ square feet of soil area will be required to carry 3,020 pounds. Therefore, a footing 18 inches wide is needed. A footing of this width should be from 9 to 12 inches deep, making it a little more than half as deep as it is wide.

Load on Each Post Footing

First and second floors, 2 times 7 times 14 times 50 lbs.	=	9,800 pounds
Attic floor, 7 times 14 times 20 lbs.	=	1,960 pounds
Partitions	=	1,000 pounds
Total load on each footing		12,760 pounds

Dividing 12,760 pounds by 2,000 pounds, the load 1 square foot will bear, gives 6.38 as the number of square feet needed to carry the load. A footing 2 feet 6 inches square has approximately the required area. Though this may seem a larger footing than is commonly used in small houses, it is needed to carry the load. Central footings with two small bearing areas are often the cause of floor settlement in residences. A footing of this type may well be "stepped down" as described in a previous paragraph.

The proper width of footings for any size of building can be determined in a similar manner.

Extend Foundations Below Frost Line

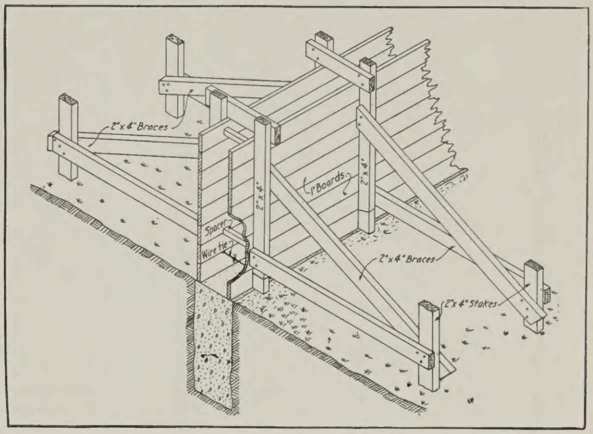
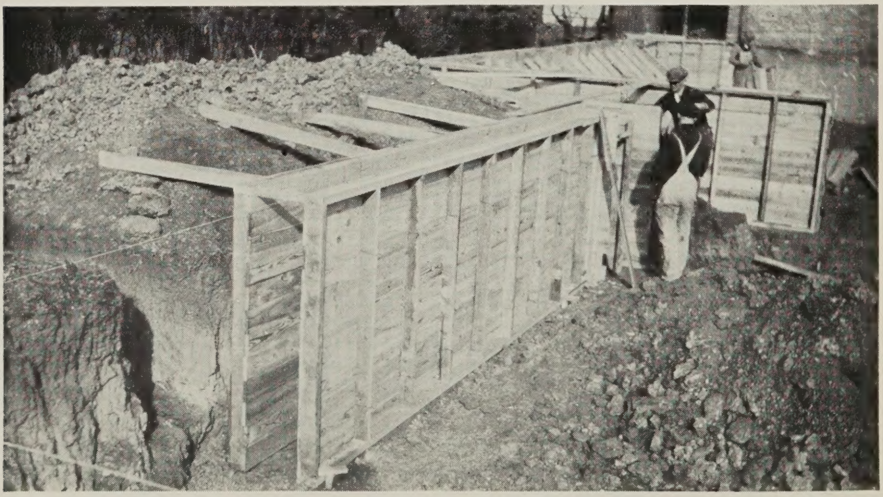


Fig. 3—Forms for monolithic walls above grade

For all types of buildings it is essential to extend the foundation below possible frost penetration even though firm bearing soil is found at a shallower depth. The foundation then will not be upheaved by freezing. In general, common practice in the community is the best guide to the depth required to get below frost. In some districts frost penetrates as deep as 6 feet.

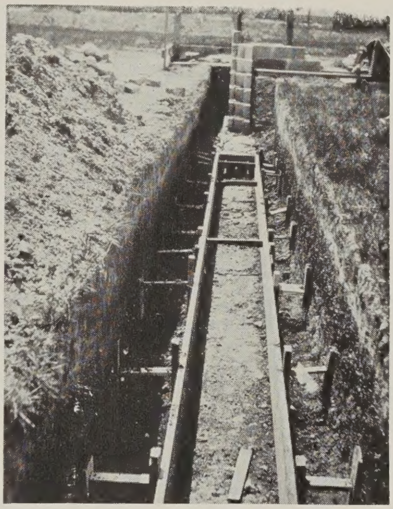
Suggested Dimensions for Foundation Walls and Footings of Small Buildings

Under the foundation walls of a barn a concrete footing 2 feet wide and 12 inches deep usually will be sufficient. Small residences generally require footings 18 inches wide and 12 inches deep. Footings 12 inches wide and 8 inches deep will serve to support icehouses, milkhouses and poultry houses. Foundation walls enclosing basements, such as for small and moderate-sized residences, generally are from 8 to 12 inches thick.



Wooden forms, when built in sections, are easily erected and removed and may be used many times. Sections should not be too long or too heavy for two men to lift. The forms shown here would be more convenient if made in sections half as long

Forms for Monolithic Foundations



Forms in place for a concrete footing. Note that a concrete block corner has been started at the far end

For small structures without basements the earth wall of the foundation trench may serve as forms if the earth is of a type that does not cave readily. The trench should be excavated carefully with sides even and vertical and bottom leveled and properly widened to receive the footing. In caving soil it is necessary to construct forms to receive the concrete.

The forms should be rigid and well braced in order to withstand the pressure of wet concrete and produce a straight, even wall without bulges or depressions. Wet concrete weighs around 150 pounds per cubic foot. Form sheathing, as well as posts and studs, must be strong enough to withstand pressure due to this weight. For walls not over 12 inches thick, 1-inch boards restrained at 24-inch intervals ordinarily will withstand pressure of concrete 3 feet deep without bulging. A 2-inch plank (nominal size) will be safe against bulging under this load with supports at 40-inch intervals. For deeper or thicker sections of walls, posts are placed closer or heavier form boards are used.

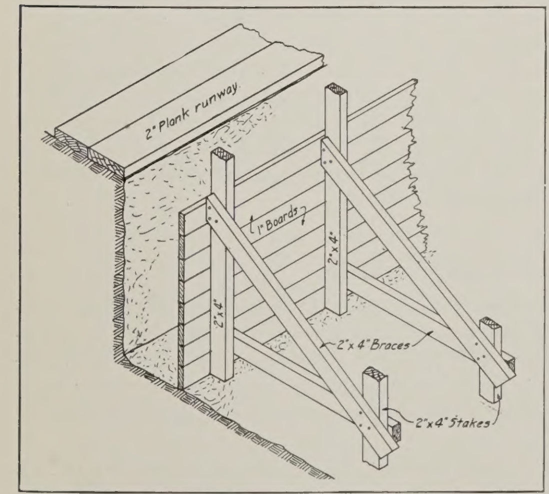


Fig. 4—Forms for foundation walls where the embankment serves as the outer form. Illustrations on page 8 show how wood forms also are used as the outer form

Posts or studs for supporting form boards or sheathing must hold forms in a true line; 2 by 4's or 2 by 6's are usually satisfactory for this purpose. These may be strengthened at intervals by wire ties run through the forms. For keeping inside form surfaces the proper distance apart, wood "spacers" or "spreaders" of a length equal to the desired wall thickness are placed between the forms before the wire ties are tightened. As forms are filled with concrete the spreaders are removed.

Forms should be constructed so that, if it is desired to use them again or to use the lumber for other work, they can be

Forms for monolithic construction must be well braced to withstand pressure of the wet concrete. Stock lengths of lumber are used without cutting whenever possible

"knocked down" with least damage to the lumber. This often is accomplished by the use of screws or special double-headed nails instead of common wire nails for holding forms together. Stock lengths of lumber often can be utilized without cutting. In that case lumber needed for other portions of the building can be used first for form lumber.

To prevent concrete from sticking to forms, crude oil, softsoap or whitewash should be painted on form faces next to the concrete. Oil drained from the automobile crankcase is satisfactory for this purpose. Surfaces are treated each time the forms are used.

Retaining Walls

For most residences and farm buildings, plain monolithic walls have strength sufficient to withstand ordinary soil pressure. Concrete masonry likewise is suitable for the construction of foundation and basement walls in residences and small buildings, and such walls usually are made of one thickness of block or tile, from 8 to 12 inches through. Walls of deep cellars and hillside locations, however, often are subjected to a heavy side pressure of soil. In such cases the foundations may be designed as gravity walls or as retaining walls. Careful design is essential, and if the builder is not familiar with the principles of structural mechanics he should consult with a competent structural engineer.

Concrete Mixes (Also see accompanying table)

For ordinary foundation conditions, concrete which attains an ultimate compressive strength of 2,000 pounds per square inch at 28 days generally is recommended. The approved mix for 2,000-pound concrete is one containing 6¼ gallons of water (with aggregates that are **damp**) for each sack of cement. (Use 5½ gallons with **wet** aggregates and 4¾ gallons if aggregates are **very wet.**)

As a trial batch, combine 1 sack cement, 2¾ cu. ft. sand and 4 cu. ft. pebbles or broken stone (1-2¾-4 trial mix), using quantities of water specified above. If this produces a mixture that is too wet, add more sand and pebbles. If too stiff a mix results, use less aggregates in succeeding batches. Do not vary the amount of mixing water except as given above.

A workable mix will take on this appearance with light trowelling

Aggregates usually are **wet** and sometimes **very wet.** In either case the amount of mixing water is reduced by the quantity present in sand and pebbles because the moisture present in the aggregates is free to act on the cement. A cubic foot of **wet** sand holds around a quart of water, while as much as a gallon may be contained in aggregates that are **very wet.**

Where the foundation is located in poorly drained soil and is to form the enclosure for a basement or cellar, water-tight concrete is desirable. **The recommended mix for water-tight concrete** is one containing not over 6 gallons of water per sack of cement. In this case a trial batch contains aggregates in the proportions of 2¼ cubic feet sand and 3 cubic feet pebbles, varied as described, to give a workable mix. The use of not to exceed 6 gallons of mixing water per sack of cement insures an impervious concrete provided sand and pebbles are added in amounts and proportions that will produce a plastic, workable mix. (See Table of Recommended Concrete Mixtures below.)

A workable mix is one that can be placed readily in the forms without separation of ingredients, and that with spading or tamping will fill all angles and corners of the forms. In a workable mixture there is sufficient cement-sand mortar to give smooth surfaces, free from rough spots, called honeycombing, and to combine the pieces of coarse aggregates into a mass that will not separate out in handling. In proportioning sand and pebbles, amounts of each may be varied as required to produce a workable mix, but water should be used exactly as given in the table.

RECOMMENDED CONCRETE MIXTURES FOR FOUNDATION WALLS AND BASEMENTS

Kind of Work	Strength in pounds per sq. in. at 28 days	Gallons of water to add to each one-sack batch if sand is			Trial Mixture for first batch			Maximum aggregate size (inches)
		Damp	Wet	Very Wet	Cement	Sand	Pebbles	
Basement floors, steps, corner posts, piers, columns	3,000	5½	5	4¼	1	2¼	3	1½
Foundation walls which need not be water-tight, mass concrete for footings, retaining walls, engine bases	2,000	6¼	5½	4¾	1	2¾	4	1½

Dowel pins are left projecting from column footings to provide anchorage for the column base

Aggregates

Aggregates for making concrete (sand and pebbles or crushed stone) should be clean and hard, free from fine dust, loam, clay or vegetable matter. Sand should be evenly graded from fine up to ¼ inch. Coarse aggregate should be well graded in sizes ranging from ¼ inch up to 1½ or 2 inches, depending upon the thickness of the foundation wall. In general, the larger pieces of aggregates should not exceed one-third the thickness of the section of concrete being placed.

The natural mixture of sand and pebbles as taken from a gravel bank, usually referred to as "bank-run" material, seldom is suitable for concrete unless first screened to separate sand from pebbles and then the two materials recombined in correct ratio.

Placing Concrete

After the concrete has been mixed thoroughly it is deposited in the forms in 6 to 12-inch layers and in a continuous operation, if possible, to avoid construction seams. The concrete will be rather stiff, requiring some tamping to get it to settle into the forms. A spade or a thin board sharpened at one end may be used for working the concrete next to the form faces to obtain smooth, even surfaces. This operation pushes large pebbles away from the surface and releases any air that may have been entrapped when concrete was placed.

It is well to complete a foundation or wall in one day's operation, if possible, in order to avoid construction seams. If it is necessary to stop work before a wall can be finished, the concrete should be leveled in the forms and the surface roughened by scratching it or by placing large pebbles in it projecting about half-way out of the concrete. This will help to secure a good bond between old and new layers of concrete when work is resumed. Before depositing an additional layer of concrete the roughened surface of old work should be scrubbed to remove any dirt or scum and just before placing new concrete it should be painted with cement and water mixed to the consistency of thick cream.

Forms may be removed as soon as concrete has hardened sufficiently to be self-sustaining. In warm weather, one or two days provides enough time for the concrete to harden so that it will stand by itself.

Curing

Moisture is necessary for the proper hardening of concrete. If this fact is kept in mind, no difficulty will be encountered in the proper curing of footings and foundations. Wall sections should be covered with moist canvas or burlap.

Cold Weather Concreting

Concrete foundations and basement walls may be placed safely even in cold weather if the fact is kept in mind that heat hastens and cold delays hardening of concrete. Winter concrete work, whether monolithic or masonry, can be a success if all materials are heated to remove frost before they are used and the finished work protected against freezing until it has hardened sufficiently to resist frost action.

Under favorable conditions concrete soon acquires sufficient strength to be safe against damage by frost. Concrete which has frozen will soften when it thaws and, for this reason, utmost precaution must be taken to maintain heat in the concrete for a reasonable length of time.

In moderately cold weather, concrete or mortar will be warmed sufficiently to insure against freezing if only the water is heated. For cold weather work it is best to heat sand, pebbles and water. Aggregates generally are heated to around 100 degrees F. Concrete masonry construction is handled easily in cold weather, as the units may be stored under cover and heated. The small amount of mortar which must be mixed on the job in concrete masonry construction generally will not offer serious difficulties in heating. Then, too, a masonry wall easily can be covered, thus retaining the heat in the walls until the mortar can harden.

Partition walls of concrete masonry units provide firesafe walls around the heating system

Economical Basement Construction

Concrete block and concrete building tile often are more convenient than monolithic concrete for the construction of foundation walls above grade and for walls enclosing basements. The units are laid up quickly and economically and provide walls of great strength and carrying capacity. No forms are required.

Plain, unsurfaced block or tile are used for walls below grade. Foundation walls above grade may be made with faced units, although the plain units often are used for that work. Plain units present a good appearance when carefully laid and pointed. Portland cement stucco sometimes is used as a covering for foundation walls above grade to provide greater refinement of finish.

Concrete foundations are the only known barriers against termites which eat and often destroy wooden structures

Concrete Masonry Foundations Are Easy To Build

A monolithic concrete footing is placed as the base for concrete masonry walls. Then the outline of the building is marked off on the smooth, level top of the footing. Units of concrete masonry are laid along this line to determine the spacing. As mortar joints between units may vary from ¼ inch to ⅜ inch, the length of wall built with a certain number of block may vary several inches and a trial laying is advisable.

After the spacing has been decided upon, the first course of block is laid in mortar. Walls then are built up at corners or intersections. Care must be taken to get these plumb and square. Intermediate sections of wall are laid to a chalk line stretched from corner to corner. Breaking of vertical joints is effected by overlapping of block at corners and by the use of half-block at openings.

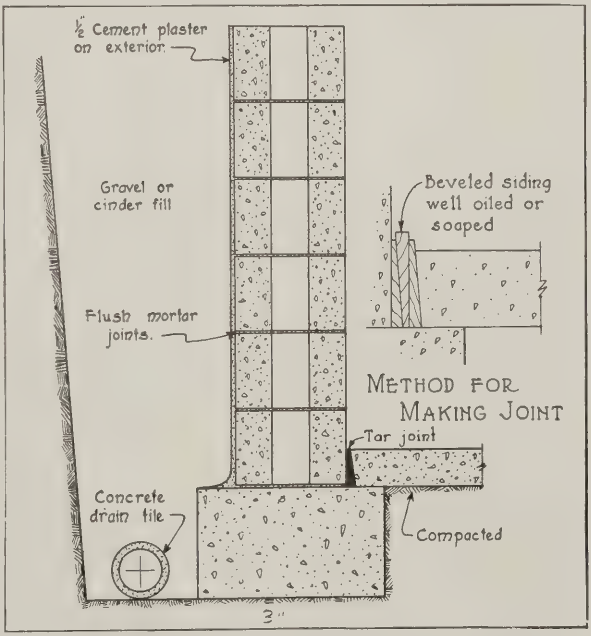
Mortar for basement or foundation wall construction is composed of 1 part portland cement and 3 parts clean sand, with 10 pounds of lime added for each sack of cement. The limited amount of lime is used to make the mortar more plastic or "fat." The sand should pass a screen having meshes ¼ inch square and should be graded evenly from fine to coarse. Mortar should be mixed thoroughly, with only enough water added to give the desired plasticity and workability. Thorough mixing improves the plasticity and less mixing water is required to obtain a workable consistency in mortar when time of mixing is increased.

Water-tight Walls Below Grade

It costs much less to build a water-tight wall than to repair a leaky one. Consequently, the time to make a basement wall water-tight is when it is built. Monolithic concrete foundations easily can be made water-tight if the amount of mixing water used in making the concrete is regulated in accordance with instructions on page 11. For concrete masonry foundations in ordinary well-drained soil, the most important precaution is to see that joints are well filled with cement mortar and carefully pointed.

It always is not easy, however, to get first-class workmanship, and in heavy, water-logged soil the pressure of water may be great enough to force its way through construction seams. The following precautions will guard against the possibility of leaks developing through defective joints. Similar methods are useful in repairing leaky basements and for insuring water-tightness in basements built of concrete block or concrete building tile.

In each case a line of concrete drain tile is placed entirely around the outside of the footing and is connected to a suitable outlet. The excavation above the tile is filled to within a foot of the grade line with soil, cinders or some other material of a porous nature to provide a fill that will allow water to seep through quickly. When the foundation is erected so near another building that it is impossible to run a line of tile around the outside, the tile may be placed on the inside of the footing and



A concrete masonry basement which has been protected against external water by proper drainage, a coating of portland cement plaster over the masonry, and water-tight joints between floor and wall

This room in the basement, utilized as a laundry, has exposed concrete ceiling. The walls of concrete block are without additional finish

slightly below it. When there is considerable water in the soil it often is advisable to place lines of tile both inside and outside of footings.

As a further precaution in securing a water-tight basement wall, two or more coats of portland cement plaster may be applied to the exterior surface as soon as wall forms are removed, or, in the case of a concrete block wall, just as soon as the mortar joints have hardened. The plaster is mixed in the proportions of 1 part cement to 3 parts sand. No lime should be used in plaster which will be in contact with the soil. Before applying the plaster, the surface should be dampened evenly to secure uniform suction.

Wall and Ceiling Treatment for Basements

If space in the basement is to be utilized completely, it is well to furr the exterior walls on the inner surface and apply a coating of portland cement plaster on metal lath. The plaster may be applied directly to partition walls of concrete masonry construction, and to exterior block or tile walls that do not require furring. Portland cement plaster on concrete masonry should consist of two base coats, each 3/8-inch thick, and a finish coat approximately 1/8-inch thick, using a 1-3 mix throughout.

In basements that are used for storage or service space, no further treatment need be given concrete ceilings than that provided by the first floor construction. If the first floor construction is of non-firesafe material, it should be covered with metal lath and portland cement plaster. Even in the case of firesafe first floors it is often advisable in the interest of cleanliness to construct a smooth, impervious ceiling of portland cement plaster.

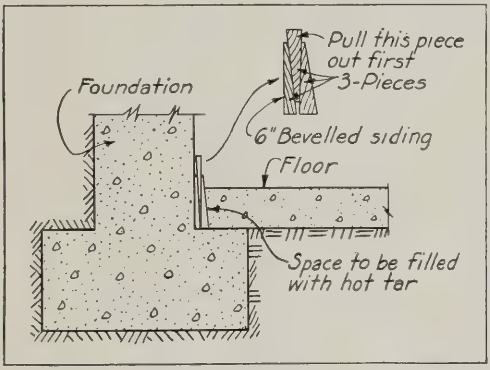


Fig. 5—Showing water-tight method of placing concrete floor on footings. Wedge-shaped joint in floor insures against seepage of water from beneath the floor

Water-tight Floors in Basements

Concrete floors in basements should be at least 4 inches thick. A 5 or 6-inch slab is desirable if unusual loads are to be supported and, where pressure of ground water is heavy, an even greater thickness is recommended. In the latter case, steel reinforcement often is used to strengthen the floor slab.

One-course construction is recommended for basement floors. This term indicates that the same mixture of concrete is used for the full thickness of the floor. The recommended mix for floors is one containing 5½ gallons of water (with aggregates that are **damp**) per sack of cement. (Use 5 gallons with **wet** aggregates and 4¼ gallons if aggregates are **very wet**.)

As a trial batch, combine 1 sack cement, 2¼ cu. ft. sand and 3 cu. ft. pebbles, using quantities of water specified above. If this produces a mixture that is too wet, add more sand and pebbles. If too dry a mix results, use less aggregates in succeeding batches. Do not vary the amount of mixing water except as given above. See page 11 for description of a workable mix and refer to table on same page for full recommendations regarding water-tight concrete mixtures before making concrete for the floor.

The concrete slab commonly is placed directly on the earth. On soil which is waterlogged, however, a fill of cinders or gravel 4 to 6 inches thick and properly drained should be placed to provide a **dry** base for the concrete. In either event, the base for the floor must be thoroughly compacted.

The surface of floors should not be finished at once but given time in which the concrete can

Building a concrete masonry basement

stiffen after it has been placed and brought to the proper level. An attempt to finish at once may produce a film of mortar on the surface which has a tendency to check or crack. The proper time to finish the floor is when the concrete has stiffened somewhat but is still workable. Finishing is performed with a wooden float. With this tool, concrete is provided with a gritty non-slip surface. Where a very smooth surface is desired, a steel trowel later is applied to the floated surface. The steel trowel forces sand particles down into the mass, tending to compact the concrete and leave the surface smooth.

Where the location of the basement is such that the ground water level is likely to rise above the floor level, further precautions should be taken to prevent leakage. The construction becomes similar to the building of a tank except that external and not internal pressure must be provided against. It may be necessary to make the walls thicker and to place reinforcement in the walls and floor. Such cases require special design for walls and floor and should be handled by an experienced structural engineer.

Attaching Sills and Plates to Concrete Wall

Sills and plates of frame structures built directly on the foundation should be bolted to the concrete wall. In monolithic wall construction, anchor bolts are imbedded in the concrete, as shown in the illustration on page 4. In concrete masonry walls, the bolts are placed in cores in the block or tile and anchored by filling around them with concrete or mortar.

Setting Door and Window Frames

Frames for doors and windows may be set before the walls are built or they may be inserted after the walls are completed. In the first case the frames are set square and plumb in proper positions in the forms before concrete is placed. Spikes are driven partly into backs of frames so that,

Raising the house preparatory to constructing a permanent and termite-proof foundation with concrete masonry units when the concrete is deposited, frames will be tied securely to the wall. When frames are set after the wall is built, rough "bucks" must be set in forms to provide the required openings. Nailing blocks are tacked lightly to the backs of the "bucks." When concrete has hardened the "bucks" are removed, leaving the nailing blocks imbedded firmly in the concrete with one surface exposed. The frames then are set and nailed to the blocks. The first method is the simpler and insures the tighter joint. It generally is used in all except the most expensive construction. In constructing concrete masonry walls the frames usually are set and built in place when the units are laid. Frames may be anchored to the wall by driving spikes partly into backs of frames at mortar joints.

Anchor bolts for plates and sills are embedded in concrete placed in the core holes

Permanent Basement Steps

Concrete steps do not wear out, get loose or become unsafe. The space under ordinary stairs where trash and vermin accumulate is eliminated with concrete steps.

Forms for cellar steps are shown on this page. The side walls are placed first, using the same type of form as in the construction of foundation walls. Earth then is filled in and thoroughly tamped to provide a firm base on which to place the concrete steps. A concrete mix using 5½ gallons of water per sack of cement is recommended for the construction of steps (1-2¼-3 trial mix). See table on page 11 for further details regarding the concrete mix.

For a comfortable flight of steps the vertical distance between treads should not exceed 7½ inches and each tread should be about 10 inches wide to permit good footing. The treads should be finished with a wood float to insure a non-slip surface.

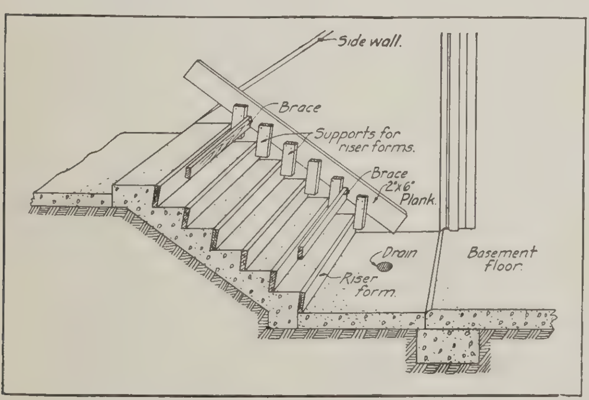


Fig. 6—Concrete basement steps are easy to build with the simple forms shown in this sketch. The concrete in the steps should be 6 inches thick or more to insure sufficient strength

A concrete foundation and first floor provides a permanent and firesafe basement for the home. Note the concrete steps built integrally with the basement wall

Concrete Piers Do Not Rot Out

Light wooden sheds, barns and frame houses without cellars should be supported on concrete piers and posts. Concrete is rotproof, fireproof, easy to build and will not require replacing. A simple form for a rectangular pier is shown on this page. Footings for piers should have sufficient bearing area to carry the load without settlement. Method for determining the size of footing is described on page 5. A concrete mixture using 5½ gallons of water per sack of cement is recommended for pier and post construction (1-2¼-3 trial mix). See table on page 11 for further details.

Piers often are built of concrete masonry. Many manufacturers of concrete products make pier block designed to support porches and light frame structures. If the base of the pier does not have sufficient area to transmit the load to the soil without settlement, a monolithic concrete footing should be placed under the pier. For block piers, mortar mixed in the proportion of 1 part portland cement, 3 parts sand and 10 pounds of lime per sack of cement is recommended. Block should be laid on a full bed of the mortar.

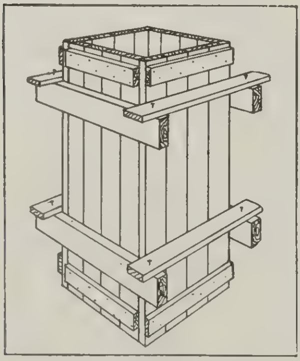


Fig. 7—A simple form that makes the construction of concrete piers easy and economical

Machine Foundations That Endure

Concrete is ideal for making foundations for gas engines, cream separators and other stationary machinery. The depth to which foundations should extend will depend on the weight of the machine and the load-bearing power of the soil. Forms for machine foundations are shown in Fig. 8. Machine foundations generally should be placed before building the floor. Then good footing on the soil can be assured. The earth or fill on which the concrete is placed must be leveled off to assure a flat, even base for the concrete, and then must be thoroughly compacted to insure against settlement due to the weight of the machine. Anchor bolts for attachment of the machinery are imbedded in concrete, using a template as shown. For ease in adjustment, a pipe sleeve larger than the bolt can be slipped over it and filled with cement grout after the machine is lined up and before it is finally bolted into place. The template is taken off after the concrete has hardened sufficiently to grip the bolts and the surface then is smoothed off with a wooden float.

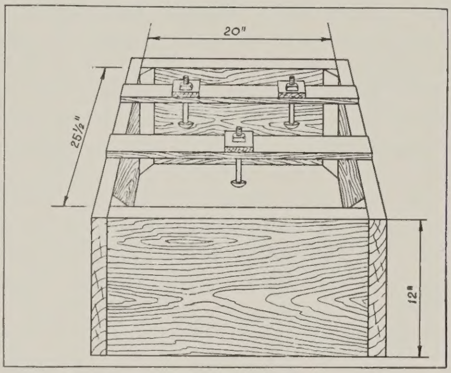


Fig. 8—This drawing shows how to make the forms for a machine foundation. The bolts are fastened to the cross strips and thus held in position while the concrete is being placed

Laying Out the Foundation

The easiest, quickest and most accurate way to determine the boundary lines of a new building is by means of surveying instruments. When such instruments are not available, one of the simplest methods for laying out corners, known as the right triangle method, can be used. A triangle with sides 6, 8 and 10 feet long is a right triangle and the 90-degree angle, or right angle, is opposite the longest side.

First, a base line is established, marking out one end or side of the new building. See line A-B in Fig. 9. Stakes are set at A and B on this line, locating two corners. In the top of Stake A a nail is driven near the center. This nail accurately locates the corner. On the line A-B another stake is driven at F, 6 feet from Stake A. A nail is driven in the top of this stake exactly 6 feet from the nail in Stake A. Stake E should be driven so that its center will be exactly 8 feet from Stake A and exactly 10 feet from Stake F. The corner represented by the angle E-A-F is a right angle; the line A-E extended to D will form the second boundary line of the building and D will represent the third corner. Other corners are located in a similar manner. After this

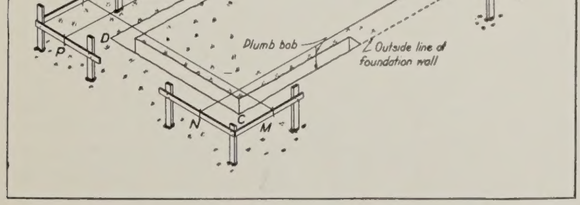


Fig. 9—This method of laying out foundations assures true walls that are right to receive the remainder of the house

has been done, strings are stretched over the corner stakes A-B-C-D and carried to outside supports called "batter boards" as indicated by G-H-K-L-M-N-P-R. The top of the horizontal batters should be set at first floor level or some other convenient "datum." The building lines may be projected from the strings to the ground by means of a plumb bob suspended as shown in the drawing. When the outside Stakes G-H-K-L, etc., have been set and the strings indicating the layout of the building transferred to them, the corner Stakes A-B-C-D and Stakes E and F are removed so that the trench may be excavated. Nails should be driven in the batters where the strings are fastened so that, if strings are broken or removed, they can be replaced accurately. Having found the building lines, it is easy to locate piers, posts, columns or other intermediate supports.

HOW TO FIGURE QUANTITIES

Quantities of cement, fine aggregate and coarse aggregate required for one cubic yard of compact mortar or concrete

(See table on page 11 for quantities of mixing water)

MIXTURES			QUANTITIES OF MATERIALS				
Cement	F.A. (Sand)	C.A. (Gravel or Stone)	Cement in Sacks	Fine Aggregate		Coarse Aggregate	
				Cu. Ft.	Cu. Yd.	Cu. Ft.	Cu. Yd.
1	2	. . .	12	24	0.9	. .	. . . .
1	3	. . .	9	27	1.0	. .	. . . .
1	1	1¾	10	10	0.37	17	0.63
1	1¾	2	8	14	0.52	16	0.59
1	2¼	3	6¼	14	0.52	19	0.70
1	2¾	4	5	14	0.52	20	0.74

1 sack cement = 1 cu. ft.; 4 sacks = 1 bbl.

Materials required for 100 sq. ft. of surface for varying thicknesses of concrete or mortar

(See Table I, page 5, for quantities of mixing water)

C. = **Cement in Sacks.**
F.A. = **Fine Aggregate (Sand).**
C.A. = **Coarse Aggregate (Pebbles or Broken Stone).**

Quantities may vary 10 per cent either way, depending upon character of aggregate used. No allowance made in table for waste.

Thickness of Mortar or Concrete (Inches)	Amount of Mortar or Concrete (Cu. Yd.)	Proportions:								
		1-2			1-3			1-1-1¾		
		C. (Sacks)	F.A. (Cu.Ft.)	C.A. (Cu.Ft.)	C. (Sacks)	F.A. (Cu.Ft.)	C.A. (Cu.Ft.)	C. (Sacks)	F.A. (Cu.Ft.)	C.A. (Cu.Ft.)
⅜	0.115	1.4	2.8	. . . .	1.0	3.0	. . . .	. . . .	. . . .	. . . .
½	0.15	1.8	3.6	. . . .	1.3	4.0	. . . .	. . . .	. . . .	. . . .
¾	0.23	2.7	5.4	. . . .	2.0	6.0	. . . .	2.3	2.3	3.9
1	0.31	3.7	7.4	. . . .	2.7	8.1	. . . .	3.1	3.1	5.3
1¼	0.38	4.5	9.0	. . . .	3.3	10.0	. . . .	3.8	3.8	6.5
1½	0.46	5.4	10.8	. . . .	4.0	12.0	. . . .	4.6	4.6	7.8
1¾	0.54	6.4	12.8	. . . .	4.7	14.1	. . . .	5.4	5.4	9.2
2	0.62	7.3	14.6	. . . .	5.4	16.2	. . . .	6.2	6.2	10.5
		1-1¾-2			1-2¼-3			1-2¾-4		
3	0.92	7.5	12.9	14.7	5.8	12.9	17.5	4.6	12.9	18.4
4	1.24	10.0	17.3	19.9	7.8	17.3	23.6	6.2	17.3	24.8
5	1.56	. . . .	. . . .	. . . .	9.8	21.7	29.6	7.8	21.8	31.2
6	1.85	. . . .	. . . .	. . . .	11.5	26.0	35.2	9.3	26.0	37.0
8	2.46	. . . .	. . . .	. . . .	15.4	34.4	46.8	12.3	34.4	49.3
10	3.08	. . . .	. . . .	. . . .	19.3	43.2	58.5	15.4	43.2	61.6
12	3.70	. . . .	. . . .	. . . .	23.1	51.8	70.4	18.5	51.8	74.0

AVERY CLASSICS

Mortar materials required for concrete masonry (8″ wall)

(Note) Amount of mortar required is subject to wide variation, depending upon wastage and how joints are made. The following figures represent general practice on the basis of 25 per cent wastage and ⅜-inch mortar joints, the mortar joints being non-continuous through the wall.

For Ordinary Work

One sack cement, 1 cu. ft. lime and 6 cu. ft. sand will make mortar to lay up the following:
150 8 by 8 by 16-inch block, or
200 5 by 8 by 12-inch concrete building tile.

For Special Work

One sack cement, 10 lb. lime and 3 cu. ft. sand will make mortar to lay up the following:
75 8 by 8 by 16-inch concrete block, or
100 5 by 8 by 12-inch concrete building tile.

HOW TO CALCULATE QUANTITIES OF MATERIALS FOR FOUNDATION WALLS

Problem 1:

What quantities of materials are required for a monolithic concrete foundation wall 34 feet square (outside measurements), 12 inches thick, 7 feet high, with a footing 12 inches thick and 24 inches wide, using a 1-2¼-3 mixture in the wall and 1-2¾-4 mixture in footing?

Solution:

The wall contains 924 square feet of surface, 12 inches thick, deducting for duplication at corners.

Referring to table under 1-2¼-3 mixture for 12-inch walls, 23.1 sacks of cement are required for each 100 square feet of surface. Dividing 924 by 100 gives the number of times 100 square feet are contained in the total wall surface and multiplying by 23.1 gives the total number of sacks of cement required. Similar calculations are made for the fine aggregate and the coarse aggregate in both the wall and the footings, noting that the width of the footing, 24 inches, is 2 times the 12-inch thickness.

$\frac{924 \times 23.1}{100}$ = 214 sacks cement

$\frac{924 \times 51.8}{100}$ = 479 cu. ft. fine aggregate

$\frac{924 \times 70.4}{100}$ = 651 cu. ft. coarse aggregate

The footing contains 264 square feet of surface, 12 inches thick, deducting for duplication at corners, or 264 cu. ft.

$\frac{264 \times 18.5}{100}$ = 49 sacks cement

$\frac{264 \times 51.8}{100}$ = 137 cu. ft. fine aggregate

$\frac{264 \times 74}{100}$ = 196 cu. ft. coarse aggregate

Total materials required for footing and wall: 263 sacks cement, 616 cu. ft. fine aggregate, 847 cu. ft. coarse aggregate.

Problem 2:

What quantities of materials are required for a 1-2 cement plaster coat, one-half inch thick on the lower four feet of the above foundation?

Solution:

Perimeter of foundation: 4 x 34 feet = 136 feet. This, multiplied by height of plaster coat, 4 ft., equals 544 sq. ft.

$\frac{544 \times 3.7}{100}$ = 20 sacks of cement

$\frac{544 \times 7.4}{100}$ = 40 cu. ft. sand

Problem 3:

What quantities of materials are required for mortar to lay up a concrete masonry basement wall requiring 750 units 8 x 8 x 16 inch in size?

Solution:

$\frac{750}{75}$ = 10 sacks of cement required

$\frac{10 \times 3}{27}$ = 1.11 cu. yd. of sand required

100 pounds of lime will be required

Building Permanently with Concrete Masonry

●

Concrete building units such as concrete block or concrete building tile bring masonry construction within the reach of everyone.

Reasonable first cost, freedom from upkeep and depreciation, great stability, maximum firesafety are outstanding advantages secured with concrete masonry units. Speed of construction is another.

For complete information about this economical method of construction—whether for small home or large warehouse—ask for your free copy of *Concrete Masonry Construction.*

●

PORTLAND CEMENT ASSOCIATION
A National Organization to Improve and Extend the Uses of Concrete

33 West Grand Avenue
CHICAGO
Offices in Principal Cities

Printed in U. S. A.

F12—10M—4-35—1—24p.